



Economic Research-Ekonomska Istraživanja

ISSN: 1331-677X (Print) 1848-9664 (Online) Journal homepage: <http://www.tandfonline.com/loi/rero20>

Is the PPP valid for the EA-11 countries? New evidence from nonlinear unit root tests

Alenka Kavkler, Darja Boršič & Jani Bekő

To cite this article: Alenka Kavkler, Darja Boršič & Jani Bekő (2016) Is the PPP valid for the EA-11 countries? New evidence from nonlinear unit root tests, Economic Research-Ekonomska Istraživanja, 29:1, 612-622, DOI: [10.1080/1331677X.2016.1189842](https://doi.org/10.1080/1331677X.2016.1189842)

To link to this article: <http://dx.doi.org/10.1080/1331677X.2016.1189842>



© 2016 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group



Published online: 16 Jun 2016.



Submit your article to this journal [↗](#)



Article views: 174



View related articles [↗](#)



View Crossmark data [↗](#)

Full Terms & Conditions of access and use can be found at
<http://www.tandfonline.com/action/journalInformation?journalCode=rero20>

Is the PPP valid for the EA-11 countries? New evidence from nonlinear unit root tests

Alenka Kavkler, Darja Boršič and Jani Bekő

Faculty of Economics and Business, University of Maribor, Slovenia

ABSTRACT

In the empirical literature there is a prevalent view that real exchange rates tend to converge towards levels predicted by the Purchasing Power Parity (PPP) only in the long-run and that short-run deviations from the PPP relationship are frequently sizable. The progressing of European monetary integration and the forming of monetary union spurred the interest of researchers to assess the relevance of the PPP theory in the case of the single European currency. Our paper therefore examines this exchange rate theory by testing a dataset of monthly real exchange rates for a sample of 11 eurozone members with respect to different benchmark currencies. Because of the documented drawbacks of linear specifications in examining this exchange rate theory, we utilise a nonlinear unit root test based on the ESTAR model proposed by Kapetanios, Shin, and Snell (2003). The results of unit root tests for the US dollar-based real exchange rate series as well as for Japanese yen-based series suggest that the PPP proposition does not hold in the case of eurozone countries. The absence of real exchange rates' nonlinear reversion reported in this study thus confirms the thesis of Wu and Lin (2011) regarding the PPP relationship since the inception of the euro.

ARTICLE HISTORY

Received 20 July 2015

Accepted 11 May 2016

KEYWORDS

Purchasing power parity;
nonlinear unit root test;
eurozone countries

JEL CLASSIFICATIONS

C20; E31; F31; F41

1. Introduction

The theory of Purchasing Power Parity (PPP) remains one of the most thoroughly investigated topics in the field of empirical international economics. In recent years researchers have been analysing various aspects of this exchange rate theory by considering a range of different methodological approaches, estimation techniques and datasets. The application of otherwise popular linear specifications by PPP testing is criticised in cases when the speed of exchange rate adjustment critically depends on the degree of deviations from the long-run equilibrium level (Taylor & Taylor, 2004). A number of factors that can be held responsible for the asymmetric adjustment of real exchange rates were summarised, for example, by Taylor (2006) and include: presence of trade barriers and transaction costs, heterogeneous interactions of traders in the foreign exchange market concerning the expected exchange

CONTACT Jani Bekő  jani.beko@um.si

© 2016 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group

This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

rate adjustment, and the coordination effects of official intervention by monetary authorities on the main traders in the foreign exchange market.

The aim of this paper is to implement, in addition to the conventional augmented Dickey-Fuller (ADF) test, the Kapetanios et al. (2003) (hereafter KSS) unit root test that accounts for possible nonlinear adjustment of real exchange rates for 11 countries of the euro area (EA-11). The empirical literature on the PPP theory for the original euro area economies is rather limited, while the results of explicit tests are surprisingly mixed (Chang, Chang, & Su, 2013; Christidou & Panagiotidis, 2010; Wu & Lin, 2011; Zhou & Kutan, 2011). From the perspective of European integration processes it is especially intriguing to observe their effects on the stationarity characteristics of real exchange rates and on the overall price convergence in this region. A second important avenue of research is to evaluate the impact of the single European currency on the functioning of PPP in the international environment. Our study focuses on these questions by testing the PPP relationship in the post-euro period with respect to different numeraire currencies.

The paper is structured as follows: Section 2 provides a brief overview of the relevant empirical literature on PPP testing for euro countries. Section 3 describes the methodology of the KSS test. The dataset employed and the empirical results are described in Section 4. Section 5 presents the implications of the study.

2. An overview of the literature

In the academic literature on PPP as well as among experts (Rogoff, 1996; Taylor, 2006) there is a dominant view that real exchange rates tend to converge on levels predicted by PPP only in the long-run and that short-run deviations from the PPP relationship are usually substantial and variable. Despite accumulating a volume of empirical research, the debate on the validity of the PPP concept is far from being settled (Taylor, 2006). The progressing of European monetary integration and the forming of monetary union spurred the interest of researchers to assess the relevance of this exchange rate theory in the case of the single European currency. Koedijk, Tims, and van Dijk (2004) analysed the relationship between the synthetic euro and eight major currencies within the SURADF model for the period 1979–2003 and gained ambiguous outcomes. Initially, they find support for the theory in the full panel of real exchange rates, but after considering the heterogeneous mean reversion in the selected sample, PPP holds only for the euro-Swiss franc series. Lopez and Papell (2007) stress that within the euro area and between the euro area and other industrial EU countries the rejection of the unit root hypothesis can be detected in the period 1996–1999. Giannellis and Papadopoulos (2010) examine national exchange rates per euro for 12 eurozone countries and conclude that between 1980 and 2000 the majority of tested real exchange rates followed an adjustment path towards PPP. For eight out of 15 EU economies, Emirmahmutoglu and Omay (2014) provided evidence of nonlinear stationarity of real exchange rates against the US dollar over the period 1988–2013 by using a sequential panel selection method in ESTAR tests.

Contrary to the above-mentioned studies, testing results for the stationarity of real exchange rates appear to be distinctly heterogeneous in the research presented by Zhou and Kutan (2011). In their cases of PPP evidence for countries in the euro area, the adjustment of real exchange rates frequently obeys nonlinear dynamics. Furthermore, Christidou and Panagiotidis (2010) could not find support for the PPP hypothesis for the original members

of the Eurozone, neither in the complete span of 1973–2009 nor in the subperiod after the introduction of the single European currency. This finding is additionally corroborated by Wu and Lin (2011) and by Huang and Yang (2015). Both studies applied Pesaran's (2007) panel unit root test allowing for cross-sectional dependencies and confirmed the mean-reversion of real exchange rates against the US dollar before the adoption of the euro, but failed to reject the null of a unit root under the euro regime. Instead of relying on bilateral exchange rates, the study by Su, Cheung, and Roca (2014) involves monthly data on real effective exchange rates for 61 countries over the period 1994 to 2012. The authors demonstrated that after considering heteroscedasticity and nonlinearity, the real effective exchange rates for the euro area as well for the majority of other countries in the sample are nonstationary.

Our overview of studies examining the long-run purchasing power parity between euro members and new EU countries shows fairly mixed results, but at the same time reflects the degree of price convergence and overall economic integration of European economies around the euro. Among papers that produced solid evidence on PPP for the new EU countries, all using euro-based exchange rates, are those written by Caporale, Ciferri, and Girardi (2011), Giannellis and Papadopoulos (2010), and by Maican and Sweeney (2013). While Caporale et al. (2011) focused on three Baltic countries testing the theory within a vector error correction model, Giannellis and Papadopoulos (2010) operated with a cluster of countries consisting of four new eurozone members and six possible eurozone candidates. In a similar way, Giannellis and Papadopoulos (2010), and Maican and Sweeney (2013) also investigated the exchange rate parity proposition by employing a range of nonlinear models, concentrating on a group of ten Central and Eastern European economies. All three studies quoted use observations that generally cover the period 1993–2005.

Some PPP-related econometric exercises provide no conclusive evidence of the empirical fulfilment of this theory. Koukouritakis (2009), for example, scrutinised the validity of PPP for 12 new EU countries using Johansen cointegration methodology. The author concludes that the long-run PPP vis-à-vis the eurozone holds only for Bulgaria, Cyprus, Romania and Slovenia. Cuestas (2009), after elaborating two sources of nonlinearities in real exchange rates against the euro, found evidence in favour of PPP for five of the eight Central and Eastern European (CEE) economies, whereas Boršič, Baharumshah, and Bekő (2012) were able to reject the unit root hypothesis by applying the panel SURADF test merely for five out of 12 euro rates of CEE countries. In addition, Karabulut, Bilgin, and Gozgor (2013) addressed the behaviour of real exchange rates in the Czech Republic, Poland and Hungary by analysing the currencies of their five largest trading partners and found weak evidence of mean reversion solely among the currencies of Hungary's main trading partners.

This paper extends the list of PPP literature given above by investigating different currencies as a numeraire and by applying the KSS test procedure on a group of 11 EU economies that were the first to officially adopt the single European currency.

3. PPP theory and econometric methodology

The absolute version of PPP theory states that a basket of goods should cost the same in two countries when the value of the basket is declared in the same currency. The relative version of purchasing power parity theory holds if the movements of relative prices of goods are offset by the movements of the prices of currencies in two observed countries in the long run. The basic model for empirical tests of the relative PPP is presented in the following form:

$$e_t = \alpha_0 + \alpha_1 p_t + \alpha_2 p_t^* + \xi_t \quad (1)$$

where e_t stands for nominal exchange rates, defined as the price of foreign currency in the units of domestic currency, p_t denotes domestic price level and p_t^* foreign price level, while ξ_t is the error term showing deviations from PPP. All the variables are used in the logarithmic form. The strict version of relative PPP contains two types of restrictions imposed on the parameters. Under $\alpha_0=0$, the symmetry restriction suggests that α_1 and α_2 are equal in absolute terms, whereas the requirement of $\alpha_1=1$ and $\alpha_2 = -1$ is referred to as the proportionality restriction.

The characteristics of real exchange rates, namely the strict version of equation (1), are most commonly explored by the empirical analysis of PPP. In accordance with the relative PPP, the changes in the nominal exchange rates should indemnify for price level shifts. Thus, a stationary time series of the real exchange rate implies that the relative version of PPP theory should hold. The nominal exchange rate and relative price levels in two observed economies determine the real exchange rate:

$$y_t = e_t + p_t^* - p_t \quad (2)$$

where y_t stands for the real exchange rate. Real exchange rates and the validity of PPP are an integral part of new open economy macroeconomics developments, which gives the PPP approach an important role in the dynamic stochastic general equilibrium models (DSGE). Among others, Ahmad, Lo, and Mykhaylova (2013) analyse the real exchange rate dynamics in the setting of DSGE models, while Clarida (2014) applies the PPP concept to optimal monetary policy outcomes in the DSGE framework.

There are several reasons that support the assumption that the adjustment of real exchange rates is nonlinear and asymmetric. As stated in Enders and Dibooglu (2001) another source of nonlinearity might arise from the well-known rigidities of national price levels in the short-run, when monetary policy changes might generate PPP deviations since prices do not react as quickly as the exchange rates. Taking into account the downward price rigidity it cannot be presumed that the real exchange rate adjustment is symmetric. Being aware of the shortcomings of linear-type empirical techniques, this paper implements a nonlinear unit root test with respect to the set of real exchange rates series in the selected euro area countries.

Kapetanios et al. (2003), also described in Bekő, Kavkler, and Boršič (2012), developed a test for the null hypothesis of the unit root against the alternative hypothesis of a nonlinear stationary smooth transition autoregressive (STAR) model. The authors attempted to distinguish between the nonstationary linear processes and the stationary nonlinear ones. The motivation for the development of the new test lies in the persistent failure of the standard ADF test to reject the null of a unit root. Consequently, two alternative frameworks for unit root testing were proposed in recent years. The first approach utilises panel tests and their higher power in comparison with standard unit root tests. The second approach incorporates stationary models other than the simple AR or ARMA under the alternative hypothesis, including nonlinear transition dynamics. Kapetanios et al. (2003) extended the last framework by analysing a particular kind of nonlinear dynamics, namely exponential smooth transition autoregressive (ESTAR) models.

The smooth transition autoregressive (STAR) model of order 1 is given by the equation

$$y_t = \beta y_{t-1} + \beta^* y_{t-1} G(\gamma, c; y_{t-d}) + \varepsilon_t, \quad t = 1, 2, \dots, T \quad d \geq 1 \quad (3)$$

where β and β^* are unknown parameters and ε_t is a sequence of independent identically distributed errors. Initially, y_t is assumed to be a zero-mean process, but the framework can easily be extended to include more general processes with non-zero mean and time trend. G represents a continuous transition function bounded between 0 and 1. The slope parameter γ is an indicator of the speed of transition between 0 and 1, whereas the threshold parameter c points to where the transition takes place. y_{t-d} is the transition variable and stands for the variable y lagged d times. The most popular functional forms are the Logistic Smooth Transition Autoregressive (LSTAR) form with logistic transition function and ESTAR with exponential transition function. The LSTAR transition function is monotonously increasing, while ESTAR is U-shaped around c and thus enables re-switching. The ESTAR functional form can be defined as

$$G(\gamma, c; y_{t-d}) = 1 - \exp(-\gamma(y_{t-d} - c)^2) \quad (4)$$

Kapetanios et al. (2003) applied the ESTAR transition function with c equal to zero. By substituting G in equation (3) with the ESTAR transition function from equation (4), we obtain the ESTAR model

$$y_t = \beta y_{t-1} + \beta^* y_{t-1} [1 - \exp(-\gamma \cdot y_{t-d}^2)] + \varepsilon_t \quad (5)$$

The null hypothesis of unit root implies $\beta = 1$ and $\gamma = 0$, since $G(0; y_{t-d}) = 0$. Model (5) postulates the nonstationary linear First-Order Autoregressive (AR(1)) model

$$y_t = \beta y_{t-1} + \varepsilon_t \quad (6)$$

under the null hypothesis and a stationary model (with $\gamma > 0$)

$$y_t = [\beta + \beta^* G(\gamma; y_{t-d})] y_{t-1} + \varepsilon_t, \quad 0 < G(\gamma; y_{t-d}) < 1 \quad (7)$$

under the alternative. When y_{t-d} is close to zero, model (7) resembles a unit root process, since $G(\gamma; 0) = 0$. For large values of y_{t-d} , on the other hand, we obtain an approximation of the linear AR(1) with the root equal to $\beta + \beta^*$. We assume that $-1 < \beta + \beta^* < 1$ (i.e. $-2 < \beta^* < 0$), as this condition implies stable roots and a stationary AR(1) model.

The null hypothesis $H_0: \gamma = 0$ needs to be tested against the alternative $H_1: \gamma > 0$. β^* is not identified under the null, and testing such a hypothesis is not feasible. To overcome this problem, Kapetanios et al. (2003) used the Taylor series approximation, as interpreted by Granger and Teräsvirta (1993). In the first step, the authors assumed $d = 1$ (which can be done without loss of generality) and respecified the ESTAR model (5) as

$$\Delta y_t = \beta^* y_{t-1} [1 - \exp(-\gamma \cdot y_{t-d}^2)] + \varepsilon_t \quad (8)$$

After replacing the right-hand side expression with its first-order Taylor approximation, one obtains the following auxiliary regression:

$$\Delta y_t = \delta y_{t-1}^3 + \text{error} \quad (9)$$

Using the t-statistic approach, the Nonlinear Augmented Dickey-Fuller (NLADF) statistic is defined as

$$NLADF = \frac{\hat{\delta}}{\sigma_{\hat{\delta}}} \quad (10)$$

where $\hat{\delta}$ denotes the Ordinary Least Squares (OLS) estimate from auxiliary regression (9) and $\sigma_{\hat{\delta}}$ its standard error.

In a more general framework, when the errors of model (8) are serially correlated, the equation is augmented with lagged differences of the process y_t :

$$\Delta y_t = \sum_{j=1}^p \beta_j \Delta y_{t-j} + \beta^* y_{t-1} [1 - \exp(-\gamma \cdot y_{t-d}^2)] + \varepsilon_t \quad (11)$$

as first proposed by Dickey and Fuller in the derivation of the ADF test. The number of lags (p) is defined as the minimal number that removes residual autocorrelation. Auxiliary regression augmented with p lagged differences can be given as

$$\Delta y_t = \sum_{j=1}^p \beta_j \Delta y_{t-j} + \delta y_{d-1}^3 + error \quad (12)$$

The NLADF test statistic is calculated from equation (10), as before. Kapetanios et al. (2003) derived the limiting nonstandard distribution of the NLADF statistic that involves Brownian motion.

4. Data and empirical results

Our sample consisted of the following eurozone countries: Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Portugal and Spain. The monthly averages of nominal exchange rates and consumer price indices were obtained from the European Central Bank and Eurostat. The real exchange rate series for US dollar rates covered the period January 1998 to February 2012, while for Japanese yen rates we calculated the real exchange rates over the period January 1996 to January 2012. The basic statistical properties of the real exchange rate series are summarised in the Appendix (Tables A1 and A2). For all countries in the sample, the consumer price indices referred to the beginning of the time period.

The results of the KSS test and the ADF test for models with constant and for models with constant and time trend are given for both numeraire currencies in Tables 1 and 2.

Estimates from the standard ADF unit root test with and without the trend component make clear that we cannot reject the null hypothesis of nonstationarity of real exchange rates for any country in the sample. This holds true for the USD-based real exchange rate series as well as for JPY-based series.

The validity of the PPP concept gains no support even if we observe the results of the nonlinear unit root test procedure for the group of 11 original eurozone members. At the conventional significance levels, the KSS test fails to reject the null hypothesis of a unit root for any individual country. Our results from testing the nonlinear adjustment of real

Table 1. Results of unit root test for US dollar rates.

Country	Trend <i>p</i> -value	Intercept			Intercept and time trend		
		No. of lags	KSS	ADF	No. of lags	KSS	ADF
Austria	0.000	1	-1.838	-1.241	1	-2.390	-2.332
Belgium	0.000	6	-1.799	-1.318	6	-2.181	-2.344
Finland	0.000	1	-1.827	-1.207	1	-2.338	-2.239
France	0.000	1	-1.912	-1.235	1	-2.499	-2.469
Germany	0.000	1	-1.834	-1.200	1	-2.379	-2.397
Ireland	0.000	1	-1.803	-1.228	1	-2.054	-2.621
Italy	0.000	1	-1.905	-1.321	1	-2.466	-2.505
Luxembourg	0.000	1	-1.852	-1.451	1	-2.486	-2.354
Netherlands	0.000	1	-1.811	-1.225	1	-2.130	-2.450
Portugal	0.000	1	-1.873	-1.343	1	-2.278	-2.576
Spain	0.000	1	-1.840	-1.442	1	-2.371	-2.554

Notes: The number of lags in the auxiliary regression is defined as the minimal number that removes residual autocorrelation. The 1, 5 and 10% asymptotic critical values for ADF with intercept are -3.46, -2.88 and -2.57, respectively. The 1, 5 and 10% asymptotic critical values for ADF with intercept and trend are -4.01, -3.43 and -3.14, respectively. The 1, 5 and 10% asymptotic critical values for KSS with intercept are -3.48, -2.93 and -2.66, respectively. The 1, 5 and 10% asymptotic critical values for KSS with intercept and trend are -3.93, -3.40 and -3.13, respectively. The critical values for KSS are taken from Kapetanios et al. (2003).

Table 2. Results of unit root test for Japanese yen rates.

Country	Trend <i>p</i> -value	Intercept			Intercept and time trend		
		No. of lags	KSS	ADF	No. of lags	KSS	ADF
Austria	0.000	1	-0.426	-0.753	1	-2.167	-1.443
Belgium	0.000	4	0.102	-0.258	4	-1.983	-1.035
Finland	0.000	1	-0.466	-0.723	1	-2.153	-1.328
France	0.000	1	-0.516	-0.820	1	-2.256	-1.512
Germany	0.000	1	-0.639	-0.846	1	-2.073	-1.448
Ireland	0.000	1	-0.895	-0.965	1	-2.598	-1.869
Italy	0.000	1	-0.486	-0.756	1	-2.316	-1.566
Luxembourg	0.000	4	0.392	-0.056	4	-1.996	-1.078
Netherlands	0.000	1	-0.645	-0.832	1	-2.492	-1.572
Portugal	0.000	1	-0.263	-0.632	1	-2.346	-1.560
Spain	0.000	1	-0.366	-0.645	1	-2.397	-1.667

Notes: The number of lags in the auxiliary regression is defined as the minimal number that removes residual autocorrelation. The 1%, 5% and 10% asymptotic critical values for ADF with intercept are -3.46, -2.88 and -2.57, respectively. The 1%, 5% and 10% asymptotic critical values for ADF with intercept and trend are -4.01, -3.43 and -3.14, respectively. The 1%, 5% and 10% asymptotic critical values for KSS with intercept are -3.48, -2.93 and -2.66, respectively. The 1%, 5% and 10% asymptotic critical values for KSS with intercept and trend are -3.93, -3.40 and -3.13, respectively. The critical values for KSS are taken from Kapetanios et al. (2003).

exchange rates for the selected euro area countries appear to be robust with respect to the inclusion of the time trend and to changes in benchmark currencies. In other words, even after considering the trend element and estimating the nonlinear adjustment of euro area economies' real exchange rates by an ESTAR model, the PPP hypothesis could not be confirmed for any of the countries in the sample, irrespective of the chosen base currency. Our empirical outcomes reported here are in line with the findings of Christidou and Panagiotidis (2010), Wu and Lin (2011), and Huang and Yang (2015). However, instead of applying Pesaran's (2007) unit root test on 11 eurozone countries, as the studies of Wu and Lin (2011), and Huang and Yang (2015) did, or testing only for a single benchmark currency (Christidou & Panagiotidis, 2010), in this paper, we carried out the KSS unit root test procedure on USD-based and JPY-based series.

A common feature of all the presented empirical results is that they invalidate the PPP for eurozone countries in the monetary-union period. The viability of purchasing power parity requires either an appropriate adjustment of nominal exchange rate through trading in foreign exchange markets or arbitrage in goods markets, which triggers shifts of relative prices of goods and services. Using detailed micro-level data from 1990 onwards for 20 industrial countries (with the exception of Ireland covering all the original eurozone countries) and the US, Bergin, Glick, and Wu (2013) showed that variations in aggregate real exchange rates are mainly due to changes of nominal exchange rates, while relative price shocks play a substantially less important role in rebuilding the real exchange rate equilibrium. The contention that responses of nominal exchange rates to real exchange rate deviations from PPP are empirically greater than the corresponding adjustment of relative prices is further strengthened by Huang and Yang (2015) for 11 eurozone economies. Moreover, the same authors have also shown that relative prices did not adjust to correct the real exchange rates along the parity lines under the euro regime. The failure of international relative prices to restore parity combined with the regime of inflexible nominal exchange rates can be an important source of violation of the long-run PPP relationship in euro area economies after 1998 (see Huang & Yang, 2015).

Nevertheless, the sufficient flexibility of relative prices of goods and services facilitates adjustment towards PPP and it is simultaneously an indicator of true integration of goods markets in the currency union. In the case of European markets, there is some evidence that this price adjustment mechanism might be functioning quite poorly. Thus, Bergin and Glick (2007) argue that a growing trade share of least traded goods, following the European monetary integration after 1998, has been associated with an increase and not decrease of price dispersion. Berka and Devereux (2013) also found no evidence for price convergence in the group of euro countries after 1999 and emphasise significant departures from PPP for nontraded as well as for traded goods. What are the underlying factors for such a development of relative prices in the eurozone markets? According to the study by Bénassy-Quéré and Coulibaly (2014), increasing product market regulations in nontradable sectors and various employment protection measures across these countries can be held responsible for the lack of adjustment in relative prices. This is a topical thesis that calls for continuous scrutiny of the PPP theory in the euro area countries.

5. Conclusions

In the literature, the presence of nonlinear dynamics in real exchange rate movements is explained with a range of models taking into account transaction costs, heterogeneous market expectations about the equilibrium nominal exchange rate, nonlinearities stemming from the goods-aggregation problem and the effects of official interventions in the foreign exchange market. Following such a line of reasoning, we employed a nonlinear unit root test based on the ESTAR model developed by Kapetanios et al. (2003) to test the PPP concept for 11 countries of the euro area.

The outcomes of the unit root tests applied in this paper for different model specifications and numeraire currencies unequivocally suggest that the PPP hypothesis does not hold in the case of the selected eurozone members after the introduction of the single currency. Our conclusion is in accord with the findings of Christidou and Panagiotidis (2010), Wu and Lin (2011), and Huang and Yang (2015) for US dollar-based series. The absence of real

exchange rates nonlinear reversion reported in this study thus confirms the thesis of Wu and Lin (2011) regarding the shift in the PPP relationship primarily since the inception of the euro. An important source of PPP breach might originate from the unresponsiveness of relative prices to readjust the real exchange rate towards its constant equilibrium under the euro regime (see Huang & Yang, 2015). It is noteworthy that some researchers have already hinted at the functioning of the price adjustment mechanism that contradicts the one predicted for the sustainable operation of the eurozone system. Bergin and Glick (2007) stress that a growing trade share of least traded goods, following the European monetary integration after 1998, has been associated with an increase and not decrease of price dispersion. Additionally, Berka and Devereux (2013) also found no evidence for price convergence in the group of euro countries after 1999 and emphasise significant departures from PPP for nontraded as well as for traded goods. Among the main quantitative drivers of relative price dispersion in eurozone markets, Bénassy-Quéré and Coulibaly (2014) identified product market regulations in nontradable sectors and employment protection measures across these countries. To what extent and when greater competition in nontradable parts of the euro economies and in the national labour markets would provoke necessary price adjustment remains, however, an open question. Given the results presented, further empirical investigation is clearly required to solve the PPP debate for the eurozone countries.

References

- Ahmad, Y., Lo, M. C., & Mykhaylova, O. (2013). Volatility and persistence of simulated DSGE real exchange rates. *Economics Letters*, 119, 38–41.
- Bekő, J., Kavkler, A., & Boršič, D. (2012). PPP and nonlinearity of real exchange rates: New evidence from transition economies. *Applied Economics Letters*, 19, 1851–1855.
- Bénassy-Quéré, A., & Coulibaly, D. (2014). The impact of market regulations on intra-European real exchange rates. *Review of World Economics*, 150, 529–556.
- Bergin, P. R., & Glick, R. (2007). Tradability, productivity, and international economic integration. *Journal of International Economics*, 73, 128–151.
- Bergin, P. R., Glick, R., & Wu, J. L. (2013). The micro-macro disconnect of purchasing power parity. *Review of Economics and Statistics*, 95, 798–812.
- Berka, M., & Devereux, M. B. (2013). Trends in European real exchange rates. *Economic Policy*, 28, 193–242.
- Boršič, D., Baharumshah, A. Z., & Bekő, J. (2012). Are we getting closer to purchasing power parity in Central and Eastern European economies? *Applied Economics Letters*, 19, 87–91.
- Caporale, G. M., Ciferri, D., & Girardi, A. (2011). Are the Baltic countries ready to adopt the euro? A generalized purchasing power parity approach. *The Manchester School*, 79, 429–454.
- Chang, T., Chang, H.-L., & Su, C.-W. (2013). Real exchange rate with nonlinear threshold effect. *Economic Research-Ekonomska Istraživanja*, 26, 167–176.
- Christidou, M., & Panagiotidis, T. (2010). Purchasing power parity and the European single currency: Some new evidence. *Economic Modelling*, 27, 1116–1123.
- Clarida, R. H. (2014). Monetary policy in open economy: Practical perspectives for pragmatic central banks. *Journal of Economic Dynamics & Control*, 49, 21–30.
- Cuestas, J. C. (2009). Purchasing power parity in central and Eastern European countries: An analysis of unit roots and nonlinearities. *Applied Economics Letters*, 16, 87–94.
- ECB Statistical Data Warehouse. (2014). Retrieved from <http://sdw.ecb.europa.eu/>
- Emirmahmutoglu, F., & Omay, T. (2014). Reexamining of PPP hypothesis: A nonlinear asymmetric heterogeneous panel unit root test. *Economic Modelling*, 40, 184–190.
- Enders, W., & Dibooglu, S. (2001). Long-run purchasing power parity with asymmetric adjustment. *Southern Economic Journal*, 68, 433–445.

- Eurostat Database. (2014). Retrieved from <http://ec.europa.eu/eurostat/data/database>
- Giannellis, N., & Papadopoulos, A. P. (2010). Nonlinear exchange rate adjustment in the enlarged eurozone: evidence and implications for candidate countries. *Review of International Economics*, 18, 741–757.
- Granger, C. W. J., & Teräsvirta, T. (1993). *Modelling Nonlinear Economic Relationships*. Oxford: Oxford University Press.
- Huang, C. H., & Yang, C. Y. (2015). European exchange rate regimes and purchasing power parity: An empirical study on eleven eurozone countries. *International Review of Economics and Finance*, 35, 100–109.
- Kapetanios, G., Shin, Y., & Snell, A. (2003). Testing for a unit root in the nonlinear STAR framework. *Journal of Econometrics*, 112, 359–379.
- Karabulut, G., Bilgin, M. H., & Gozgor, G. (2013). Purchasing power parity hypothesis: Mixed evidence from Eastern Europe emerging markets. *Emerging Markets Finance & Trade*, 49, 213–227.
- Koedijk, K. G., Tims, B., & van Dijk, M. A. (2004). Purchasing power parity and the euro area. *Journal of International Money and Finance*, 23, 1081–1107.
- Koukouritakis, M. (2009). Testing the purchasing power parity: Evidence from the new EU countries. *Applied Economics Letters*, 16, 39–44.
- Lopez, C., & Papell, D. H. (2007). Convergence to purchasing power parity at the commencement of the euro. *Review of International Economics*, 15, 1–16.
- Maican, F. G., & Sweeney, R. J. (2013). Real exchange rate adjustment in European transition countries. *Journal of Banking & Finance*, 37, 907–926.
- Pesaran, M. H. (2007). A simple panel unit root test in the presence of cross-section dependence. *Journal of Applied Econometrics*, 22, 265–312.
- Rogoff, K. (1996). The purchasing power parity puzzle. *Journal of Economic Literature*, 34, 647–668.
- Su, J. J., Cheung, A., & Roca, E. (2014). Does purchasing power parity hold? New evidence from wild-bootstrapped nonlinear unit root tests in the presence of heteroskedasticity. *Economic Modelling*, 36, 161–171.
- Taylor, M. P. (2006). “Real exchange rates and purchasing power parity: Mean-reversion in economic thought. *Applied Financial Economics*, 16, 1–17.
- Taylor, A. M., & Taylor, M. P. (2004). The purchasing power parity debate. *Journal of Economic Perspectives*, 18, 135–158.
- Wu, Y., & Lin, E. S. (2011). Does purchasing power parity hold following the launch of the euro? Evidence from the panel unit root test. *Applied Economics Letters*, 18, 167–172.
- Zhou, S., & Kutan, A. M. (2011). Is the evidence for PPP reliable? A sustainability examination of the stationarity of real exchange rates. *Journal of Banking & Finance*, 35, 2479–2490.

Appendix

Table A1. Descriptive statistics of logs of real exchange rates for US dollar.

	AT_USD	BE_USD	DE_USD	ES_USD	FI_USD	FR_USD	IE_USD	IT_USD	LU_USD	NL_USD	PT_USD
Mean	0.163812	0.162578	0.161686	0.179019	0.152618	0.169824	0.197911	0.172500	0.175009	0.181082	0.183485
Median	0.197774	0.200057	0.197595	0.199073	0.189578	0.196560	0.213375	0.194628	0.201424	0.195978	0.197598
Max	0.508154	0.494964	0.504447	0.470881	0.513180	0.510106	0.491579	0.502598	0.475364	0.525764	0.495789
Min	-0.179245	-0.180007	-0.190551	-0.122313	-0.211162	-0.170942	-0.132735	-0.153948	-0.143244	-0.173726	-0.137607
Std. Dev.	0.185549	0.178332	0.193273	0.150557	0.195774	0.184691	0.166520	0.171786	0.156353	0.181510	0.164202
Skewness	-0.292760	-0.347120	-0.271234	-0.419035	-0.307485	-0.252556	-0.313543	-0.299953	-0.413041	-0.276773	-0.321523
Kurtosis	1.949599	2.054325	1.880635	2.310424	1.945795	1.933170	2.185696	2.077193	2.265751	2.079748	2.181856

Webpage links to the data sources:
Eurostat database (2014): <http://ec.europa.eu/eurostat/data/database>
ECB Statistical Data Warehouse (2014): <http://sdw.ecb.europa.eu/>

Table A2. Descriptive statistics of logs of real exchange rates for Japanese yen.

	AT_YEN	BE_YEN	DE_YEN	ES_YEN	FI_YEN	FR_YEN	IE_YEN	IT_YEN	LU_YEN	NL_YEN	PT_YEN
Mean	4.896205	4.897887	4.892043	4.923217	4.886271	4.902149	4.943409	4.911372	4.915072	4.920922	4.926767
Median	4.923701	4.927598	4.919582	4.932254	4.912400	4.924481	4.925670	4.923708	4.934621	4.922301	4.927560
Max	5.218921	5.234801	5.196223	5.309191	5.209846	5.224337	5.340339	5.262156	5.284495	5.287022	5.302806
Min	4.462798	4.450512	4.482004	4.447832	4.446623	4.478970	4.530526	4.461659	4.429349	4.493599	4.459996
Std. Dev.	0.163804	0.171894	0.157177	0.191247	0.169465	0.160866	0.182767	0.175885	0.184635	0.174447	0.182418
Skewness	-0.437468	-0.433336	-0.416966	-0.232825	-0.357334	-0.393090	0.194355	-0.308005	-0.404806	-0.101648	-0.119666
Kurtosis	2.509661	2.559432	2.386007	2.709038	2.304845	2.490800	2.455292	2.573954	2.773989	2.383257	2.630954

Webpage links to the data sources:
Eurostat database (2014): <http://ec.europa.eu/eurostat/data/database>
ECB Statistical Data Warehouse (2014): <http://sdw.ecb.europa.eu/>